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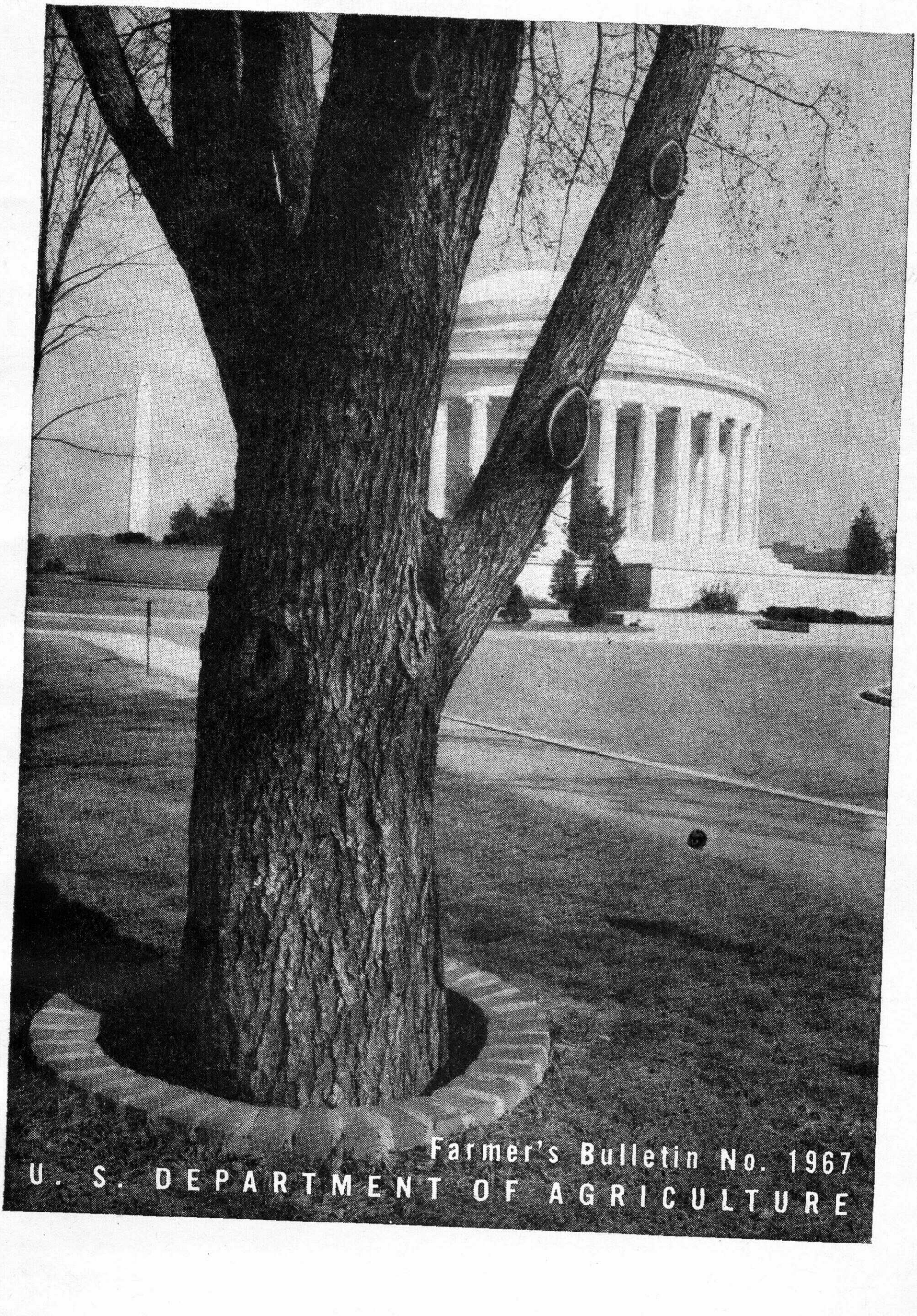
Reducing Damage to Trees from Construction Work



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U. S. DEPARTMENT OF AGRICULTURE

ADVANCE planning is desirable for the tree protection that will be needed in postwar construction of roads and buildings. Early in World War II directions for protecting trees were prepared for the special use of the military. This information, now available for general use, includes directions needed by contractors, builders, park superintendents, highway engineers, home owners, and others to prevent or lessen damage to trees from construction work and to remedy any damage already done. These directions are summarized as follows:

Before beginning construction and development work, take due precautions to minimize the possible damage to selected valuable trees.

Thin wooded areas gradually.

Preserve natural soil fertility by saving topsoil and leaf litter. Exercise extreme care in making marked changes in the ground around trees.

Provide for air and water movement when preparing a fill over tree roots. Do not cut too many feeding roots when lowering grades; terrace whenever possible.

Place simple protective barriers around trees to prevent excessive injury to trunks and roots.

If attempts are to be made to save trees already injured, treat wounds promptly to lessen the spread of decay into exposed wood.

Do not mutilate trees by improper pruning for wire clearance.

Locate roads so as to preserve valuable trees.

Prevent unnecessary erosion of exposed embankments.

Avoid soil packing and tree-root suffocation in car-parking areas.

Obtain competent assistance in handling perplexing problems.

Frequently it would cost less to protect and preserve large and highly desirable trees already growing on an area than to remove them after they die and to replace them with smaller and less valuable plantings.

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REDUCING DAMAGE TO TREES FROM CONSTRUCTION WORK

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CONSTRUCTION WORK in wooded areas has frequently led to the sacrifice of many valuable trees some of which could have been saved but for the fact that arrangements were made either too late or not at all. Nearly everyone recognizes the value of trees in providing shade, ornament, or protection for building sites, city streets, and roadsides. All too frequently, however, the trees that made a site attractive have been mutilated or killed by carelessness, inadequate protection, or failure to appreciate their requirements.

The many hazards to which trees are subject are intensified by mechanical injuries and environmental changes due to construction work, though the damage is not always immediately evident. Many trees apparently uninjured, later reveal wounds that at first were concealed. Often the most serious injuries are covered by an earth fill. Usually the visible parts of the tree are affected before the full extent of the damage is properly evaluated—then it may be too late for remedial measures.

A building site may greatly decrease in value or completely lose its desirability by the serious injury or death of important trees. Such trees should be safeguarded against unnecessary and avoidable severe injury during construction work. Recently transplanted trees usually have less value for shade and ornament than long-established ones.

Frequently it is possible to repair injuries to a tree or to restore it to health, but it is always better and usually more economical to prevent damage than to correct it. Before actual construction is begun it is worth while to give careful thought to the protection of trees on the site. During the early stages of the operation it is often possible by a slight modification of plans to adjust alinements and grades so as to minimize injury to valuable key trees.

It is important to keep in mind that a tree is a living entity that can develop and thrive only in surroundings which are suitable to its needs or to which it has become acclimated. Like other living organisms it respires, absorbs moisture and nutrients, grows, matures, and reproduces. Its very life is dependent upon an effective working relationship between its different parts and also between the tree and its environment—below as well as above ground.

Damage to trees from construction work falls into two broad categories: (1) Mechanical injuries to roots, trunks, and branches; and (2) injuries resulting from fundamental changes in growing conditions. Of the two, those of the second group are perhaps the more serious, since they are often caused by conditions not readily recognized and the damaging effects are slower in becoming visible.

PLANNED PROTECTION

The formulation of a sound policy as to whether in pending construction work a particular tree should be let alone, protected by modification of plans, given preventive or corrective treatment, or removed altogether is a matter to be decided on the values at stake. Tree values vary widely but usually can be judged by such factors as location, size, age, species, and vigor.

The relation of a tree to its surroundings is of major importance in determining the effort and expense that would be justified in treatment or in changing construction plans so as to avoid injury. If a tree is standing near a home, along a driveway, in a park, or on a roadside, or if it has important historical or sentimental associations, the value will be proportionately greater than that of comparable trees less favorably situated. If there are other trees of equal merit nearby, the value of an individual tree may be greatly lessened. On areas with only scattered trees, all may be sufficiently valuable to justify protection. Where there are many trees, all that are not in the direct path of construction or that do not unduly hamper the workmen may well be kept until the construction work is completed and the effect of the loss of others can be better judged.

Size, age, and species are important considerations. Small trees are easily replaced—many times at less expense than preserving the original trees. Very old trees usually do not respond favorably to a changed environment, but owing to location or historical association they may be of such value as to justify great expense in attempting to preserve them. If an old tree is badly rotted or unsafe it may be better to remove it than to expend any effort in preserving it. A healthy tree of a normally long-lived species is more worthy of treatment than a short-lived one because of its greater life expectancy.

In general, young, vigorously growing trees should be favored in making a choice, as they will withstand adverse conditions and changes better than old trees or those of less vigor. Trees subjected to severe grade changes, those having a large proportion of their roots cut, and those suddenly exposed by thinning to unaccustomed sun and wind undergo severe stress and fundamental changes and may require special measures simply to keep them alive. Length of annual twig growth, size and color of leaves, the rate at which wounds heal, and comparisons with nearby trees of the same

species are simple indexes for determining vigor. Trees that are susceptible to serious disease or insect attacks are generally less valuable than others. Also, they are usually less responsive to protective treatment than those with a greater degree of immunity.

THINNING WOODED AREAS

Thinning that results from the dying or indiscriminate removal of the trees in a forest tends to disturb the natural conditions that determine the composition of the tree community and the health of its members. If the trees are quite dense, the removal of the less desirable ones may benefit those that remain by reducing competition for moisture, nutrients, and light. Difficulties are sometimes encountered, however, when improvement cuttings are designed to convert such stands into open woodland or when large openings are made in the forest canopy. The damage increases with the severity and rapidity of the thinning. Trees that formerly grew in partial to dense shade are suddenly exposed to increased sunlight, to drying winds, and to more violent temperature changes. Care must be exercised in thinning stands of trees, especially with some conifers. Such stands should be thinned cautiously so as to avoid windthrow and breakage. Greater precaution is necessary with shallow-rooted than with deep-rooted species and with trees growing on wet or heavy soils; root development usually is more shallow on moist sites or heavy soils than on dry sites and light soils.

Trees with a well-developed root system are generally less susceptible to windthrow than those whose roots have been restricted by competition in dense stands; the taller the trees, the greater the hazard of thinning. Indentations on the edge of a forest are dangerous, but isolated trees are seldom thrown. There is danger of air-current "funneling" if thinning is done carelessly, particularly at the end of a valley. Breaks in the canopy, which permit initial wind entrance, should be avoided, particularly V- or egg-shaped cuttings, as they produce a funneling effect.

Danger from windthrow sometimes can be reduced by pruning the tops of trees subjected to this type of damage.. In some cases it is advisable to support mechanically strategic trees whose roots have been cut or those that are suddenly exposed to winds of unaccustomed intensity or direction. Such support may be provided by cables anchored in the ground and attached by eyebolts to the upper trunk, or by cabling weakened trees to others more firmly rooted. In felling trees, whether singly or in groups, care must be exercised to prevent a falling tree from striking and wounding those that are to be retained.

A tree may not adapt itself readily to the changed environment brought about by thinning, and in its weakened condition it may be attacked by secondary fungus and insect pests. It is important, therefore, to thin gradually—over a period of years, if possible—and to protect from the adverse effects of necessary thinning any remaining trees that have appreciable value.

To lessen the danger from sunscald and attack by bark beetles and insect borers, trunks and large branches of important thin-barked deciduous trees that have been suddenly exposed to the direct sunlight may be wrapped or waxed. Such treatment retards transpiration and thus lessens damage from drying winds. For wrapping, either burlap or a special paper is

usually available at seed stores and nurseries. Apply the wrapping material as a spiral bandage, extending it downward from the larger branches to the base of the tree, so that each turn overlaps the preceding one by half the width of the material. The bandage should be tied firmly in place and left on for 2 years, or until it rots off.

In establishing camp grounds in forests it is usually desirable to retain all the trees and shrubs in as nearly a natural condition as possible. The location of the camp's main features—roads, parking spurs for automobiles, stoves, tables, and cabin or tent sites—should be planned for the convenience of the campers and should utilize available shade without creating unfavorable growing conditions for the trees. By locating camp features so as to avoid as many trees as possible and by providing protective barriers to minimize injury to the trees that remain, the site can be used for an indefinite period and still retain an almost natural forest cover.

SAVING TOPSOIL AND LEAF LITTER

Forest trees are usually well adapted to the specific conditions under which they occur. Soil quality is one of the important factors that determine their growth and health; and when soil is disturbed by grading, it is often completely changed in character. The topsoil beneath a tree may be essential to its welfare; its removal usually causes serious damage. The topsoil on an area to be occupied by buildings should be scraped aside and saved for spreading in a thin layer under trees needing soil improvement and on bare road embankments. It can also be used as a base before lawn seeding and in the planting holes for new trees.

In a naturally wooded area rotted leaf litter and duff should be left on the ground to improve moisture conditions. If such materials have been removed, it is advisable to supply them from some other source and, if necessary, to maintain low-growing plants that will prevent undecomposed leaves from blowing away. The risk of fire, blowing of leaves, or other factors, however, may make it desirable to remove dry fallen leaves and ground litter temporarily, but they may be composted and later used as a top dressing beneath the trees if economically feasible. This practice helps to maintain the fertility, humus content, and moisture-absorbing and moisture-holding capacity of the soil. In large forested areas the fire hazard may be reduced by raking dry leaves from around buildings and roadsides and using firebreaks to isolate forest compartments.

RAISING GRADES

EFFECT ON TREES

Fill construction around existing trees is more than a simple engineering problem of raising grades. If it is desired to save the trees and maintain their vigor, the problem must be approached with an understanding of the effect of overburden on tree life and health. To function normally, tree roots must have an adequate supply of both water and air. Soil organisms also affect tree health. Sudden changes in the air and water content of the soil upset the normal functions of these organisms and may adversely affect the tree roots.

If their roots are covered continuously with water, nearly all trees will die because they are unable to obtain sufficient oxygen from the water.

A deep fill tends to raise the water table or increase the moisture content of the soil until many roots are suffocated. The normal exchange of soil gases and air also may be retarded by a deep or relatively impervious fill. Even a shallow fill made over heavy turf or thick leaf litter may so change the normal gaseous condition around tree roots as to damage the trees seriously or even kill them.

The feeding roots of a normal undisturbed tree spread outward from the trunk in all directions, sometimes considerably beyond the spread of the branches. Most of them lie within 18 inches of the ground surface, although there is considerable variation between species and among trees of a single species when growing under different conditions. The application of a layer of several inches of porous gravelly soil usually will do little or no harm. Impervious fills, even if very shallow, are much more injurious, as they admit little or no air and water to the feeding roots and may materially raise the water table or cause surface drainage to be dammed up over the roots. It is often more economical and usually safer to maintain a normal balance of air and water around the roots when making the fill than to attempt to correct adverse conditions after completion of the work.

No single method of constructing fills over tree roots fits all circumstances. Considerable judgment and ingenuity must be exercised in solving a specific problem in a manner that will give maximum benefit for each dollar expended. The value of a particular tree in its location, the environment in which it is growing, its age and vigor, the materials available, and the cost of the operation in contrast with the loss that might be incurred should the tree be sacrificed are only a few of the factors that have to be taken into account. For example, it would be obviously impractical to spend a large sum to preserve a single tree on a roadside if there are a number of comparable trees in the immediate vicinity or if the tree is an average member of a forest community. It would be highly practical, however, to install an elaborate protection system for an outstanding specimen or group of trees on the lawn of a private home or public building.

No series of controlled experiments has been conducted to test the various methods of making fills over tree roots. Many observations have been made by competent workers, however, and some rather definite procedures are now generally accepted. The following method of constructing a porous fill is satisfactory in most circumstances for protecting trees of considerable importance. It may be modified as described on page 11 if local conditions warrant.

FILL CONSTRUCTION

Before making a fill, remove the green vegetation, sod, leaf litter, and other organic matter from beneath the trees and loosen the surface soil without injuring the tree roots. It may be advantageous to apply fertilizers at this time. For broadleaf trees most authorities recommend an application of a complete mineral fertilizer well distributed within the root area at the rate of 1 to 3 pounds for each inch of tree diameter. About half this quantity is recommended for conifers. Organic fertilizers may be injurious if the subsequent fill is to be deep or if the original soil is overmoist or poorly drained. The formulas for the commercial fertilizers

generally used vary from 6 to 10 percent nitrogen, 3 to 8 percent phosphoric acid, and 3 to 6 percent potash.

Tiling

After preparing the soil surface, place porous agricultural drain tiles on the ground in lines that will drain away from the tree trunk (fig. 1).

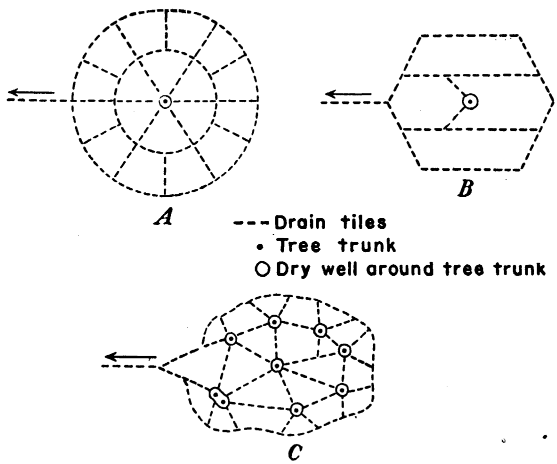


FIGURE 1.—Arrangement of drain tile on original surface of ground where a fill is to be made. The tiles are placed so as to drain in the direction indicated by arrows. *A*, Tiles laid in lines radiating from tree trunk and connected to drain off water at outlet. Center of pattern only may serve for a small tree; for larger trees additional drainage may be provided by extending the tiling as indicated. *B*, Parallel lines of tiles sometimes may be used advantageously. *C*, Suggested arrangement of tile drains for a group of trees.

Usually 4-inch tiles are used. If necessary for drainage, the tiles should be laid in trenches deep enough to maintain the normal water tables. Care should be taken to insure that they will drain off excess water. A drop of one-eighth inch per foot is adequate. If there is any doubt whether the system will drain freely, verify with a level or test with water before covering the tiles.

Determine the tile pattern by the location of the tree roots and the economical use of materials (fig. 1). If trees are very close together, parallel lines of tile may provide all the drainage necessary. In other cases, the pattern may form a series of rectangles or squares. For an isolated tree, the pattern may be that of the rim and spokes of a wheel. On steep slopes the water may drain satisfactorily through a prepared fill without the use of tile, but tile may be necessary to intercept and drain excess water from higher elevations above the tree. Cover the top part of the tile joints with an impervious material, such as tar paper or strips of old tin, to keep out dirt and debris that might clog the system. It is essential that the drains be kept open. If they become clogged, water may back up into the prepared fill and cause trouble. It is especially important that all outlets be well protected—with screening, if necessary—so that they will not become clogged and impair the whole system.

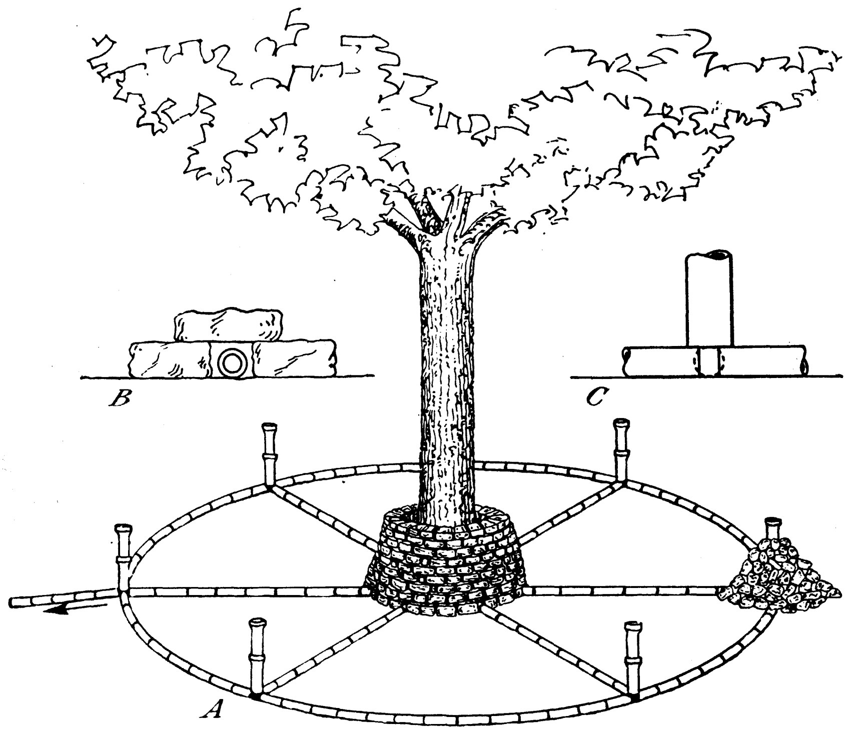


FIGURE 2.—Preliminary steps in constructing a fill. *A*, Dry well around tree trunk to permit air and water circulation. Tiles on ground sloped so as to drain away from trunk and off the roots, as indicated by arrow. Vertical tiles connected with the drain will permit additional air circulation; the one on the extreme right is held erect by loose stones. *B*, Protecting arch of stone placed over drain tiles to prevent breakage. *C*, Vertical tile resting on the ends of horizontal tiles that are spaced to allow circulation.

Dry Wells

Construct a dry well around each tree trunk, leaving enough space for future increase in trunk diameter (fig. 2, *A*). The well may be built 6 or 8 inches from the trunk of an old slow-growing tree; the clearance given the trunk of a younger tree must be relatively greater. The well should be built high enough to bring the coping just above the level of the proposed fill. This will prevent surface drainage, sediment, and debris from being washed into the well. One or more of the drain-tile lines should begin at the lowest point inside the well, which is built of large stones, bricks, building tiles, concrete blocks, or cinder blocks. Care must be taken, however, to insure ample openings through its wall, and excessive remnants of lime mortar should be avoided. Hollow tiles, concrete blocks, or cinder blocks should be placed so that the hollows extend through the wall (fig. 3). These materials can be bedded in mortar, as free air and water movement will be provided through the hollows in the wall. In constructing a well from stone, mortar should be used only near the top of the well above the porous fill. Because of their regular outline, bricks may be spaced with large openings between them and mortar used to bed the points of contact.

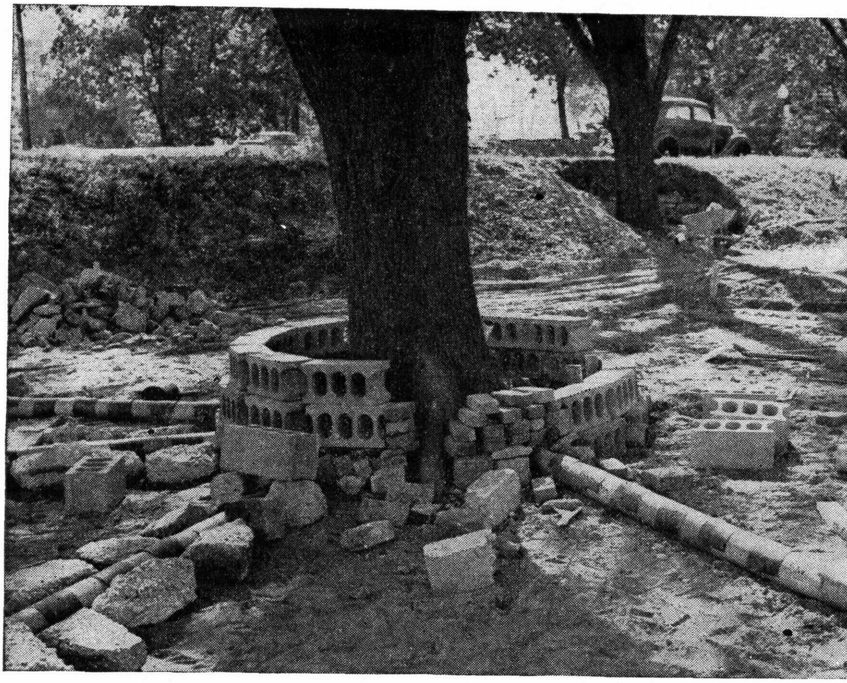


FIGURE 3.—Concrete blocks with hollows that extend through the wall provide the necessary openings into the stone-filled layer. Turning the blocks or using solid materials near the top of the well will prevent soil from sifting through the wall into the well.

A well made with loosely placed stones or bricks must be nearly perpendicular, or it may not stand. The use of building blocks, with a coping of bricks, as shown by the illustration on the cover, permits the well to be large at the base and corbeled toward the top, to conform with the shape of the tree trunk. This smaller exposed opening reduces the accident hazard. Large openings may be covered with gratings or have barriers erected around them if they endanger pedestrians, especially children.

Some authorities recommend that wells be filled with alternate layers or mixtures of charcoal and sand; others that stones be placed loosely in the wells. These materials, especially the finer ones, lessen the free movement of air. As the tree trunk grows larger, stones in the well may become embedded in the tree trunk unless they are removed occasionally and replaced loosely in the well. It is satisfactory to leave the well open if it is cleaned frequently to remove sediment, leaves, and debris, which might interfere with the free passage of air and water into the fill or might gradually work into and clog the drain tile. Shields or screens may be used to cover the mouths of the drain tiles in the bottom of the well.

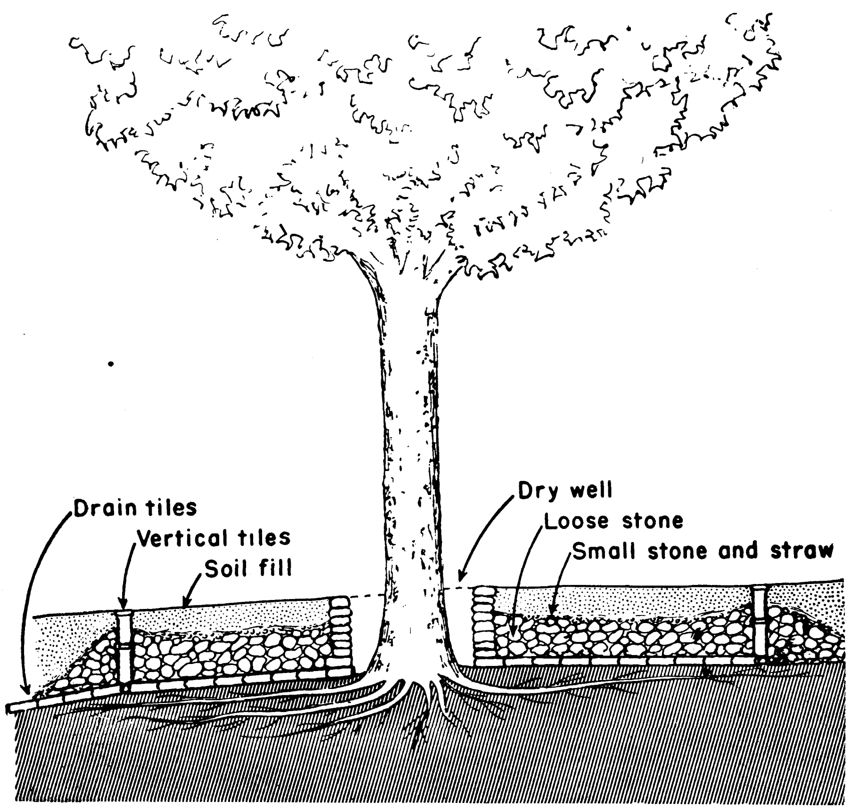
Air Circulation

Unless tree trunks are close together and dry wells frequent, it may be necessary to provide for additional air circulation. This is best done by erecting several vertical bell tiles at the intersections and connecting them with the tile drains (fig. 2, *C*). Blocking with stones will hold them erect

(fig. 2, *A*). Glazed 6-inch bell tiles are usually used. The tiles are placed so that the bells will just reach the surface of the ground when the fill is completed. These vertical tiles should extend just high enough and the ground in the immediate vicinity be so sloped that surface water and debris will not wash in. While making the fill, cover the mouths of the bell tiles with some such material as tar paper or a wood or rock plug, to prevent sifting in of debris and dirt. After the fill is made, the bell tiles may be left open unless such openings will prove dangerous. A heavy-mesh screen may be placed over the openings to keep out debris or the openings may be filled with loose stones that will still permit sufficient air movement.

Place large stones on each side and over the top of the drain tiles to form a protecting arch (fig. 2, *B*). Then place a layer of large stones, preferably 3 to 6 inches in diameter or larger, over the entire area under the tree from the well and out at least as far as the tree's branches extend. Be careful not to break the drain tiles. For total fills of 2 to 3 feet, 8 inches to 1 foot of stones is usually adequate, but more stones are needed in a deeper fill. It is doubtful whether much more than 30 inches of stones is ever needed over most of the tree's roots. The stones should rise gradually near the tree well until they come to within a foot of the top. Provide

FIGURE 4.—Cross section of completed dry well and fill.



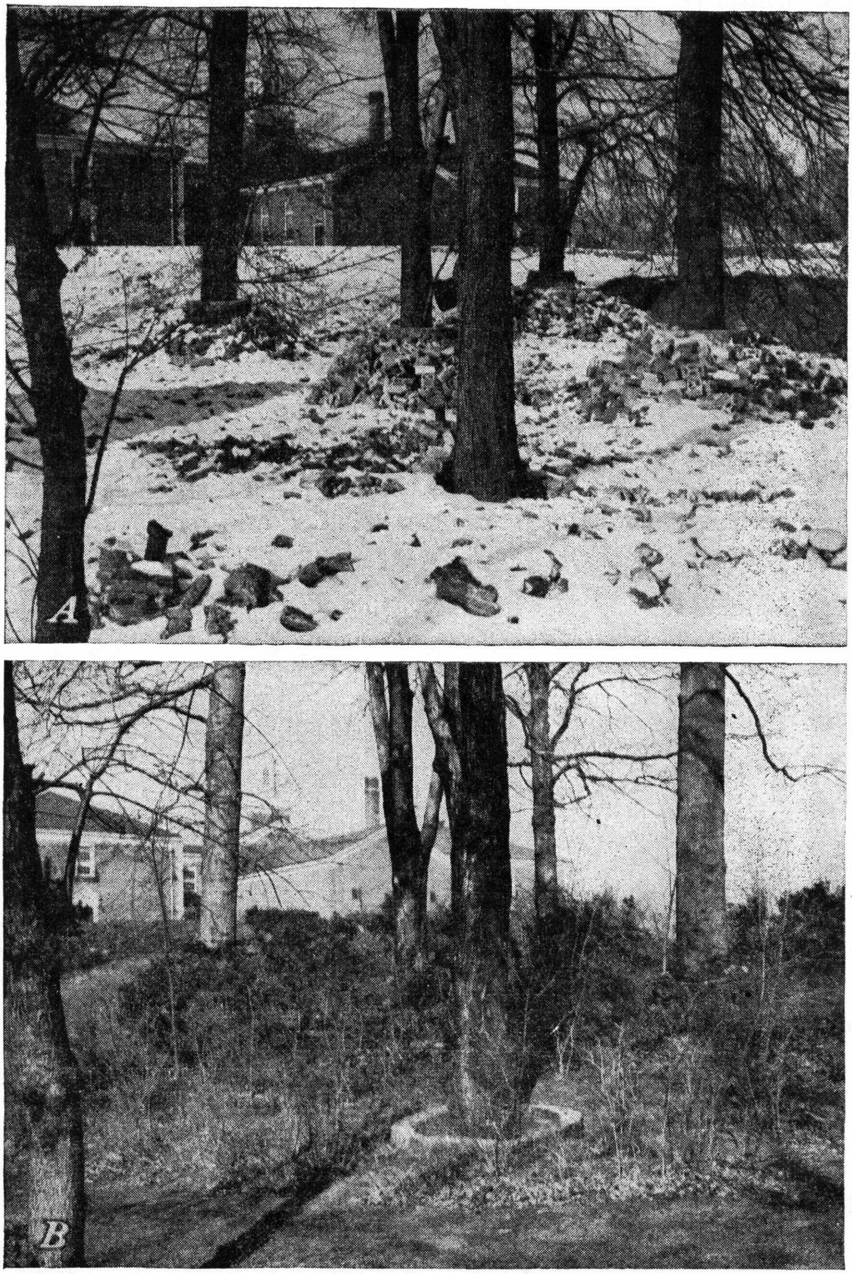


FIGURE 5.—Properly constructed fill around five large trees: *A*, Fill under construction; *B*, satisfactorily growing trees 4 years after the fill was completed.

numerous air pockets among the stones. To supply oxygen to the tree roots and remove harmful gases, air must flow steadily through the dry well, the bell tiles, and the porous stone fill.

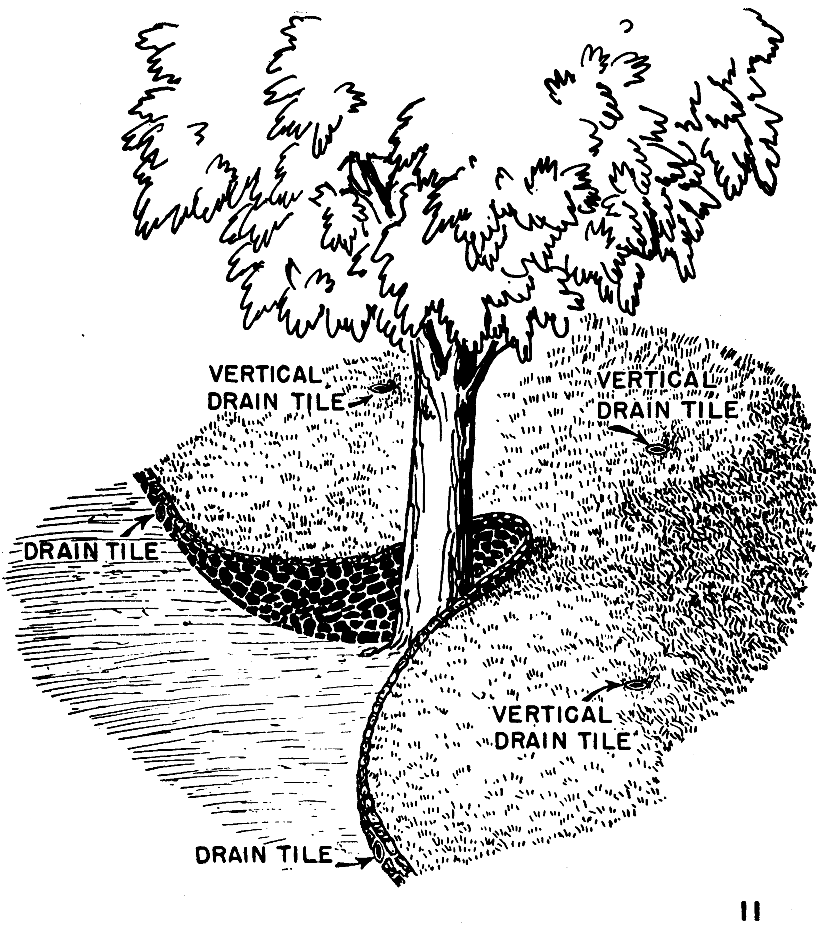
Place a shallow layer of gravel over the large stones to fill the surface openings and to prevent soil sifting down between the stones. It is a common practice to lay a thin layer of dry hay, straw, or pine needles over the gravel. Complete the fill by adding porous soil until the desired level is reached (fig. 4). The depth of soil and stone should be adjusted as required, so that the soil will be adequate to support the type of surface vegetation desired on the area.

The fill under construction in figure 5, *A*, enabled five large trees to continue satisfactory growth. After four growing seasons (fig. 5, *B*) they showed no ill effects from having the grade raised 3 to 7 feet.

Modification of Construction

The system of providing aeration and drainage in a fill can be adapted to various conditions. For example, at the edge of a steep filled slope the dry well around a tree may be left open at the lower side (fig. 6). If a group of trees was originally on a well-drained slope, it may be possible

FIGURE 6.—Open dry well at edge of filled slope provides air and water circulation over the part of the root system covered by the prepared fill. Extending the upper side of the wall a few inches above the fill prevents debris washing into the well.

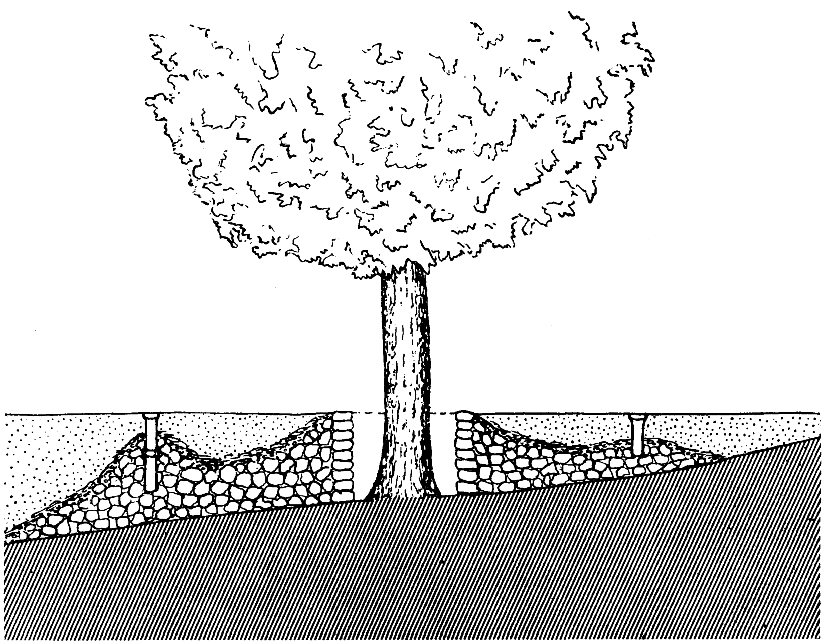


to obtain sufficient drainage through the fill by using stones or coarse gravel only and omitting the tile drains (fig. 7). The drains afford so much better chance of success, however, that their use is justifiable under most conditions.

If economy is essential or the questionable value of a tree will not permit the expense involved in the construction of a complete aeration system, several variations may be adopted. It should be realized, however, that the tree's chances for survival are lessened somewhat thereby. The horizontal tile field may sometimes be omitted if adequate drainage is otherwise assured. If blind wells can be constructed to connect the soil surface with the porous fill, it may be satisfactory to omit the vertical tiles. Even the tree well is sometimes omitted if the porous rock fill can be coned up to the surface around the tree trunk. Coarse gravel as a substitute for porous fill constructed of larger stones has proved satisfactory in a number of cases. Efforts to effect economy by constructing a dry well around a tree trunk, however, and then making an earth fill without the use of stone or other porous material, often fail. Superficially such trees appear to have been properly treated, but later, even after several years, they may become weakened or die.

Even the best aeration systems cannot insure the life of a tree, but each economy effected by omitting parts of the method described to construct fills properly around a valuable tree may lessen its chances for survival. If, in addition to grade changes, a tree has been subjected to a marked change of exposure by thinning operations, its chance for survival is still less. Trees around which the grade has been raised should be watched carefully for several years to be sure that the protection system is function-

FIGURE 7.—Cross section of fill constructed on a well-drained slope. Adequate drainage sometimes may be obtained through using loose stone without tile drains, but vertical tiles will increase air circulation.



ing effectively. If symptoms of trouble appear, remedial treatment should be prompt and thorough.

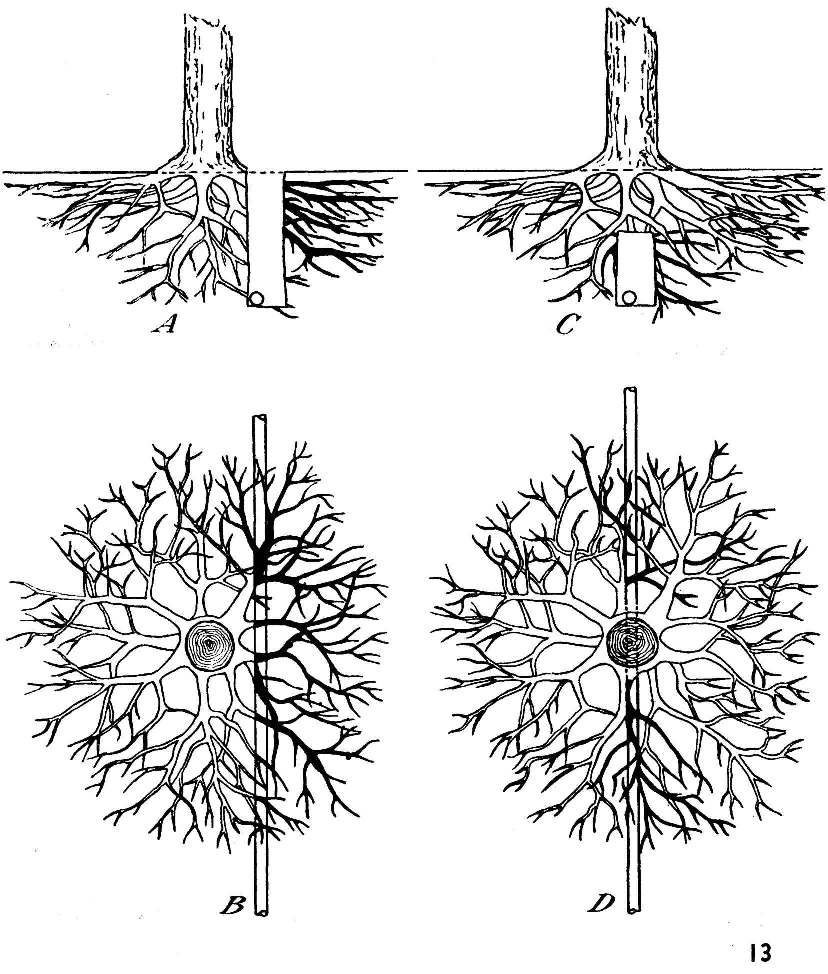
In some areas, where continuous fills have been made or are to be made over large areas, it is extremely difficult or impracticable to provide adequate drainage and protection for trees. Prospective purchasers of such property should realize that the original trees on the ground have little chance of surviving.

LOWERING GRADES

EFFECT ON TREES

When deep soil cuts are made over the entire area occupied by the roots, it is difficult to maintain the life and health of trees. In most areas, even a shallow cut of 6 or 8 inches will remove not only a large part of the

FIGURE 8.—Roots severed by digging trenches near a tree. Severed roots are indicated in solid black. Side and top view: *A* and *B*, Many roots destroyed by trenching close to a tree trunk; *C* and *D*, only a few roots destroyed by trenching directly toward the trunk and tunneling under the base of the tree.

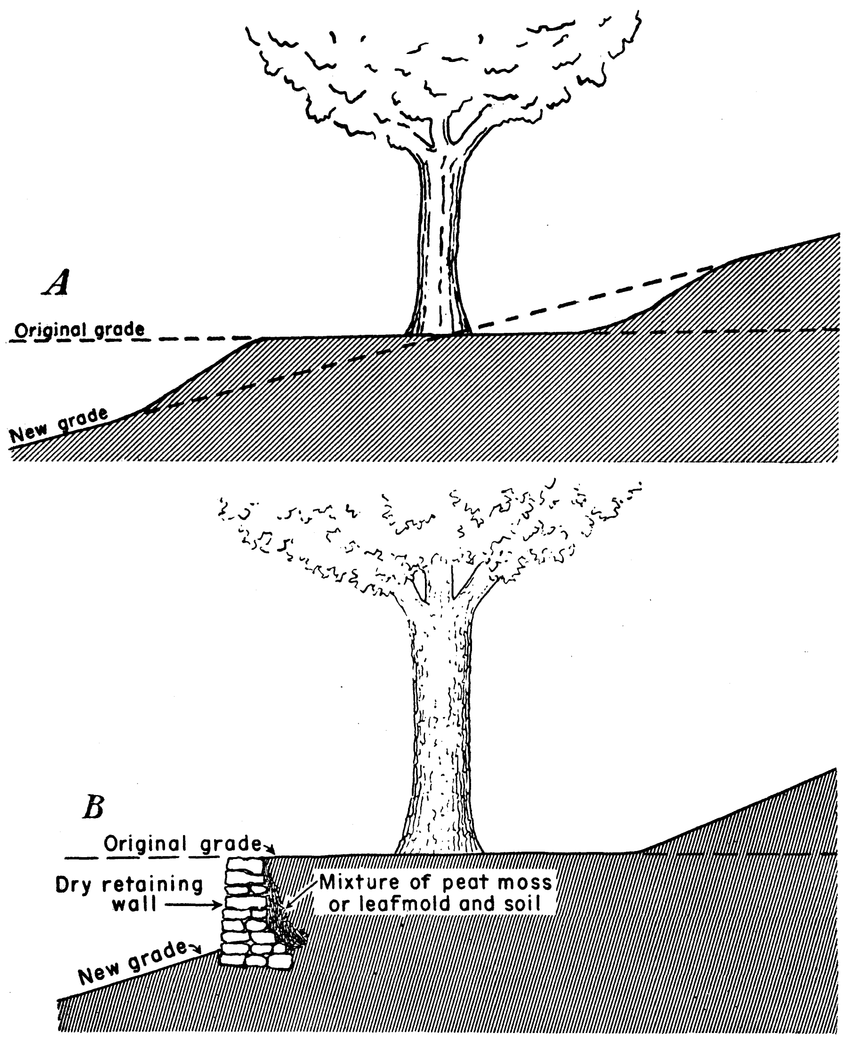


good topsoil, and sometimes all of it, but also many of the feeding roots. Deep cuts may sever large important roots, thus depriving the tree of anchorage and increasing the danger of windthrow.

Lowering the grade tends to lower the water table if it is near the surface. It may also cause excessive root and soil drying by removing the protective topsoil, natural mulch, and vegetation. Some trees are severely affected by changes in soil-moisture conditions, especially by raising or lowering the water table. Therefore, as few grade changes as possible should be made.

In digging foundations and trenches or in making road embankments it is often necessary to cut off part of a tree's root system. One-third to one-half of the roots are commonly destroyed when excavations are made near a tree trunk.

FIGURE 9.—Preserving a maximum number of tree roots when the general grade is lowered: *A*, By terracing; *B*, by erecting a dry retaining wall.



When a large part of the roots cease to function, the leaf surface must be reduced proportionately to balance the reduced root system or the tree will suffer from induced drought and possibly starvation. If roots are cut during the growing season, the top of the tree should be pruned at once; if they are cut during the winter, the pruning should be completed prior to the next growing season.

To avoid cutting too many roots of a valuable tree when trenches are dug, it is sometimes advisable to zigzag or curve the trenches or even to tunnel under important large roots. On trees that do not have a large taproot, fewer roots are severed if trenches are dug directly toward the trunk and the trench tunneled under the base of the tree rather than close to one side (fig. 8). Sometimes it is better to drive pipes under tree roots rather than to place them in prepared tunnels. Pipes should be driven to the side of where taproots would normally be located.

Roots should not be left exposed in the drying air. They should be covered promptly with soil or kept moistened with wet burlap or peat moss. The injured ends of mutilated roots should be cut off smoothly and painted promptly with a wound dressing. Trenches should be backfilled as soon as possible, and air pockets in the soil should be avoided. Peat moss or other humus material added to the backfill will be advantageous in inducing new root growth.

By terracing (fig. 9, *A*) or by erecting a dry retaining wall (fig. 9, *B*) grades can sometimes be lowered around trees without cutting off too many of the feeding roots. It is best not to seal the retaining wall with mortar. If mortar must be used to build the wall with the materials available, voids should be left at frequent intervals through the wall for air circulation and drainage. A mixture of peat moss or leafmold and soil should be placed behind the wall to improve the moisture-holding capacity of the soil. If enough roots are retained and branches are pruned promptly and judiciously, the tree may remain alive and healthy.

Engineering considerations may sometimes demand that a structure or a roadway be built at a level that would necessitate lowering the grade over all the root area of a valuable tree. Often it is possible to save such trees by leaving a gradually sloped mound beneath the tree (fig. 10, *A*) and erecting a retaining wall at one or more of the abrupt cuts (fig. 10, *B*). Such walls as these do not necessarily have to be dry walls, but are often sealed with mortar.

If topsoil high in organic matter is to be removed during grading, it should be retained and some of it later returned to the soil surface as a dressing. Do not destroy more of the tree's root system than necessary by making the cut deep enough to provide for the return of a large quantity of topsoil. If cuts are made in clay soil, it is usually advisable to loosen the exposed subsoil before returning any of the topsoil, taking precautions not to damage the tree roots.

In most cases of cutting the roots those that remain should be stimulated. Fertilizers applied 2 to 3 feet under the surface through holes punched in the soil with a heavy bar or made with a compressed-air drill will encourage deeper root penetration or development. A surface mulch of leaves, leafmold, well-rotted manure, peat moss, clean straw, hay, or other coarse organic material will greatly improve the moisture-absorbing and

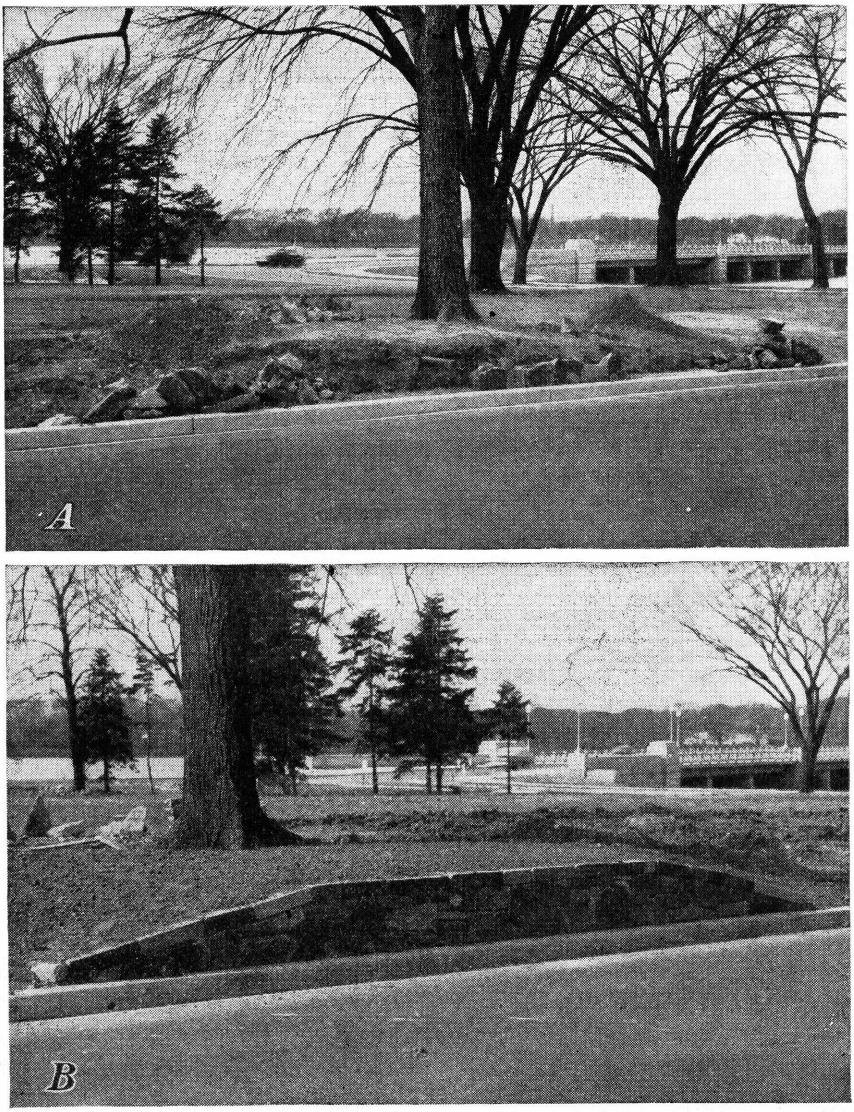


FIGURE 10.—Roots are saved and soil is held by (*A*) leaving a gradually sloped mound beneath a tree and (*B*) erecting a retaining wall at the edge of an abrupt cut.

moisture-retaining capacity of the soil. The mulch will eventually rot and add humus to the soil, thus improving its texture. Water will more readily soak into such soil and will not evaporate so readily from it. Mulches also help to retard the erosion of freshly worked soils and are beneficial in reestablishing ground-cover plants. They also keep the soil warmer in winter and cooler in summer and retard rapid temperature changes.

If the water table has been lowered by grading or if there is a prolonged period of drought, some trees will need additional water. If water is applied, let it soak deeply into the soil. Watering that wets only the surface will not supply the large quantities required by a tree. It may even prove to be harmful by compacting the surface soil and encouraging root development too near the surface. A low ridge of soil will prevent rapid runoff and thus permit deeper penetration of the water.

CORRECTING EXISTING DAMAGE

CAUSE AND EXTENT OF DAMAGE

In the construction of buildings and roads many cuts and fills have been made without regard to tree protection. The situation has frequently become especially acute when speed was essential and advance planning neglected. Overlays of soil and waste building materials have been left on the ground beneath trees, and trenches have often remained open for long periods. The soil may have been removed without due consideration to the tree injury that results. Traffic, even by pedestrians, may have seriously compacted the soil.

Wilted or faded foliage, premature dropping of the foliage, undersized leaves, excessive sprouting along the main stem and branches, and dying of twigs and branches are some of the external symptoms of root injury. If enough roots have already been injured and killed to make these symptoms pronounced, it is difficult to preserve the affected trees. It should be noted, however, that these general symptoms may also be caused by certain parasitic fungi and insects or by conditions unrelated to construction damage.

Numerous fungi and insects, ordinarily of secondary importance, may attack trees weakened by construction damage and may increase so rapidly as to be the immediate cause of the death of such trees. The presence of these organisms should not mislead anyone as to the basic cause of the trouble. Sometimes the secondary pests need specific treatment, such as given in the publications listed on page 26. Usually the prompt treatment of construction damage and restoration of the tree to normal vigor should be the primary objectives. The presence and abundance of certain pests sometimes indicates the state of health of a tree better than the external appearance of the tree itself. For example, a heavy infestation of ambrosia beetles is usually an indication that the tree is so far gone that there is little if any hope for recovery, even though the foliage for a time may appear normal.

It is often difficult to estimate the extent of construction damage to trees. One tree appears to be doomed by the severity of a cut or fill but continues to live, while another unexpectedly dies after only a slight change

in its environment. Some species of trees are less susceptible to injury than others, but none can survive too radical changes in growing conditions. The elm, poplar, willow, planetree, ailanthus, and locust are among those trees considered by many as less susceptible to damage by grade changes. The oak, maple, beech, birch, hickory, and the conifers are considered to be more susceptible to such injury.

REMEDIAL MEASURES FOR EXISTING EARTH FILLS

Before extensive remedial work is begun, the vigor of a tree should be determined, as suggested on page 2, but this work should not be delayed while a valuable tree is becoming further weakened. Sometimes prompt treatment will save a tree that would receive little if any benefit if the same treatment were delayed too long.

Treatment of trees suffering from the effects of earth fills will, of course, vary with local conditions—the degree of injury, the depth and character of the fill and the length of time it has been in place, and the species and age of the tree. It is necessary to observe carefully the various parts of the affected tree, especially the roots. There is little hope of recovery if a substantial part of the fibrous roots are water-soaked, discolored, or dead, if a strong, gaseous odor is encountered, or if the bark of the buried trunk is loose and the cambium layer beneath the outer bark is discolored. If the injury is less severe, however, there is often a reasonable chance that prompt treatment will save the tree.

Loosening the soil with a spading fork, carefully so as not to injure the roots, will help to correct compacted surface soils. Compressed air may be used to fracture deeply compacted soils, provided they are not water-soaked. Under very wet conditions compressed air does little good and may cause additional packing and puddling, but in moderately moist or dry soils it may give temporary relief to a tree injured by earth fills. Compressed air is applied by means of a special auger, or "gun," through holes previously drilled with a soil auger. This forces out accumulated noxious gases and permits air and water to reach the tree's feeding roots. The compressed air should be blown into the soil at 4- to 6-foot intervals throughout the area occupied by the roots. The beneficial effect of the treatment may be prolonged by keeping open the air-injection holes or by filling them with gravel or coarse sand.

If the fill is not too deep and is composed of soil porous enough to be suitable for root growth, occasional treatments with air may cure the trouble. If not, they may prevent serious damage until other remedial measures can be taken. For fills that will become compacted again and shut off air and water from the roots, compressed air would be of little value unless reapplied when needed. In such cases it should be followed immediately by a more permanent treatment.

If the fill consists of heavy soil, it is best to remove it entirely from the area under the spread of the branches of the tree or beyond. Provision should be made for suitable drainage to get rid of excessive soil moisture and to prevent the collection of water in the depression. If possible, the excavation should be left open until the tree shows signs of recovery or indicates by growth and appearance that it is not declining. A well may then be constructed around the tree trunk and a porous fill made as previously described.

If the foregoing procedure is deemed too expensive it can be modified for economy, but at greater risk of losing the tree. The following method has shown fair results: The filled soil close to the tree trunk is removed and radial trenches are dug from the trunk out as far as the branches spread, or beyond. The ends of these trenches are connected by a circular trench. A connecting tile system is then placed in the trenches and arranged so as to drain the area. (See p. 6.) A dry well is constructed around the tree trunk, and then rocks, crushed stone, and gravel are placed over the drain tiles in the manner described on pages 9 and 11 for making a fill. The remaining space in the trenches is then filled with porous soil. Instead of having a dry well, the tree trunk sometimes has an area around it filled with stone and gravel or charcoal and sand.

Another type of treatment that may overcome some of the harmful effects of a fill is to dig a number of holes down through the fill to the original soil level and fill these holes with loose stones or other porous material. These blind wells will serve as breathing pores for part of the root system, but they are not at all satisfactory if they accumulate and hold water. The more blind wells constructed, the better chance the tree has to recover.

Pruning the top to compensate for root losses will be helpful.

OVERCOMING INJURY FROM GRADING CUTS AND TRENCHING

After making grading cuts or digging trenches, replace the topsoil or backfill the trenches as soon as possible. If the surface soil does not contain abundant humus, it should be supplemented with leafmold, compost, well-rotted manure, or peat moss. Some of the feeding roots undoubtedly will have been destroyed. Prune protruding or badly injured roots back to healthy tissue. The application of a mineral fertilizer to the soil will benefit the roots that remain, and watering and mulching will be helpful.

Prune the top of the tree sufficiently to balance the remaining roots. If one-fourth of the feeding roots have been destroyed, the leaf surface also should be reduced at least one-fourth. Do not head back too severely. The tree top can be reduced by removing lateral branches and thinning rather than by topping. The value of a tree may be impaired by improper pruning as well as by lack of pruning.

MECHANICAL INJURIES

Most mechanical injuries to trees involved in construction work are preventable, if the hazards involved are understood and if suitable precautions are taken in time. All supervisors, foremen, and workmen concerned should be informed of the serious tree damage that results from carelessness, from collision by trucks, bulldozers, power shovels, and other equipment, from improperly blanketed blasting operations, from consolidation of the soil over roots, from fire, from girdling by guy wires, and from unnecessary root cutting and drying. Frequently, they must be educated to a true appreciation of tree values. In addition, suitable protective devices should be placed to prevent mechanical injuries.

A board frame around a tree or other barrier on the side exposed to danger will prevent much damage to the bark by trucks or other vehicles.

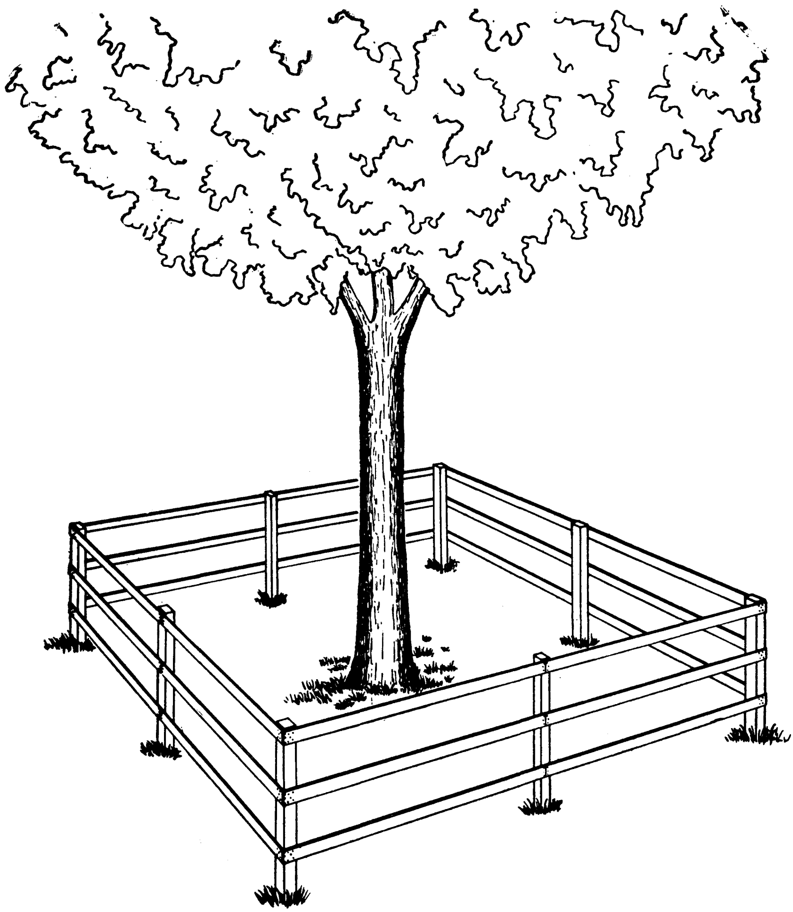


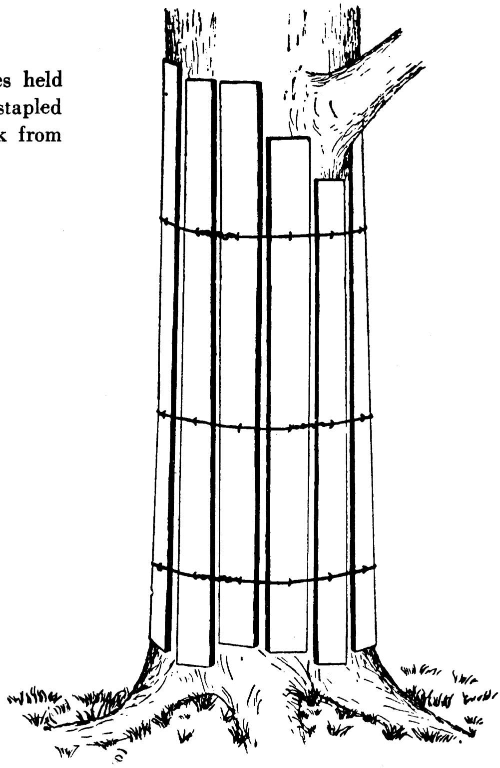
FIGURE 11.—A simple barrier to protect the tree trunk and part of the root system from mechanical injury.

Preferably, barriers should be located far enough away from the trunk to prevent consolidation and puddling of the soil over the root system. Trucks or other heavy equipment should be kept as far away from the tree trunks and roots as practicable (fig. 11).

On the lower side of road slopes, where large rocks are likely to roll against and injure tree trunks, the bark of valuable trees may be protected by poles, boards, or slabs, lashed or wired in an upright position against the trunk (fig. 12).

It is more effective to blanket blasting operations than attempt to protect individual trunks, as the rocks hurled through the air may strike and injure the tree above the protected area. When blasting is done in the vicinity of trees, the slowest explosive that will do the job should be selected and shots should be blanketed with blasting mats. These are heavy mats woven of 1- to 1½-inch hemp rope, steel-wire rope, or chains that are placed over the loaded holes to catch material flying from the blast. For heavy blasts,

FIGURE 12.—Planks or split poles held firmly against a tree trunk by stapled wires or rope will protect bark from much mechanical injury.



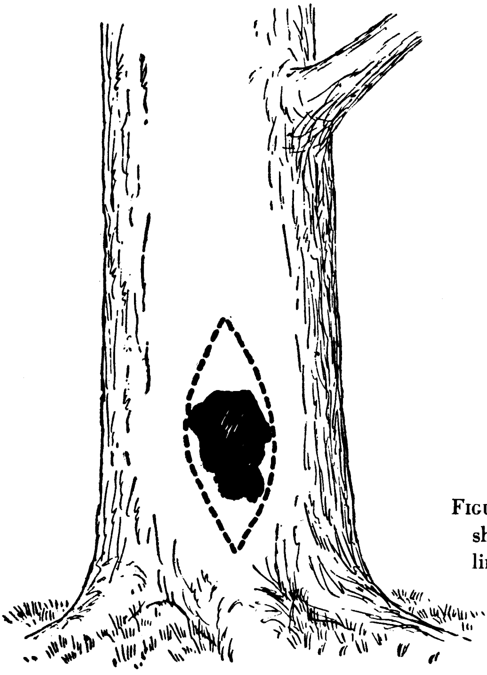


FIGURE 13.—Irregular wounds should be shaped as indicated by the broken lines, to facilitate healing.

logs are sometimes put down first and the mats are placed on top of them. Brush used alone to blanket the blast is seldom effective.

If despite these precautions the bark is severely bruised or is knocked or stripped off a tree trunk or large branch, the resulting wounds should receive prompt treatment. Remove the dead tissue and trace the bark edge back to a streamlined shape to facilitate healing (fig. 13); then treat the surface of the exposed wood with a wound dressing to reduce the decay hazard.

Occasionally, *very prompt* tacking of the bark in place and painting the exposed tissues with shellac before they dry out will result in the healing over of the area. The bark must be tacked in place before the tissues dry, to afford any chance of success. During the growing season close inspection should be made of the area within 6 weeks. If the work is done during the dormant season, inspection should be made within 6 weeks after tree growth starts in the spring. If the wound is not healing, the dead bark should be removed and the wound treated as described in the preceding paragraph. Dead bark must not be left to conceal an untreated wound.

Another method of treating surface wounds has recently been described. It has been found that bark will form directly over many newly made wounds if the cambium layer is not disturbed and the wounds are shaded from the sun's rays. The wound should be edged with a sharp knife to remove loose bark, but only the edges are to be shellacked. All other contact with the open wound is avoided, to prevent contamination. Shade is provided by screens of new burlap or canvas attached to wooden stakes set in the ground close to the base of the tree. The shades are kept in position 4 to 8 weeks.

Some investigators have reported that lanolin, when used as a wound dressing on a number of species of trees, results in less damage to the exposed tissues and much more rapid development of callus over wounds than other materials used, including shellac. This work suggests that a lanolin tree paint may be developed as a desirable substitute for some other types of wound dressing.

Low-hanging branches that may be injured by vehicles or higher branches that interfere with building construction should be pruned carefully. Such pruning should follow accepted methods with all cuts made flush with the parent limb or trunk and with cut surfaces painted with the best wound dressing available. It is far better to remove unwanted branches in a desirable manner than to risk their mutilation.

Guy wires carelessly wrapped around tree trunks are responsible for many injuries. If it is necessary to use a tree as an anchor for a temporary guy wire, it is a simple matter to insert sufficient blocks between the wire and the trunk to prevent injury to the tree. Permanent guys should be attached to eyebolts or lag hooks inserted into the trunk or branches, never wrapped around them.

Fire hazard is always present during construction work. It is a temptation to dispose of trash and debris by touching a match to it; a cigarette can result in serious consequences if carelessly dropped in dried leaves or grass. Leaves may be raked away from buildings and tree trunks, and, if necessary, dried grass may be cut or burned under careful control if the hazard is severe. In forested areas, fire lanes may be created to isolate one section from another and to serve as a line from which to fight a fire if one occurs. Fires for warming and trash disposal should be built only

in safe places where they cannot spread, scorch overhanging branches, or injure the bark and roots of trees and shrubs. Even the heat and soot from steam rollers, asphalt heaters, and other equipment can be injurious to foliage; hence all possible care should be taken to minimize damage from these causes.

As mentioned on page 15, trenches for sewers and water pipes and cellar excavations should be backfilled as promptly as possible, to lessen root injury and hasten new growth.

Care should be exercised to store building materials and trash where they will not damage tree trunks or consolidate the soil over root systems.

CLEARANCE FOR OVERHEAD WIRES

It is vitally necessary to keep cross-country power and communication lines functioning continuously. Local distribution lines also are important. Obviously, wires that are strung close to trees or through their tops are subject to more breakage than those where the tree hazard is removed or is nonexistent. The creation of forest lanes to make room for high-tension lines usually results in straight unsightly gashes. Another factor to be considered is that straight gashes in the forest, particularly in coniferous stands, create artificial canyons through which wind rushes with an intensity to which the root systems and trunks of the marginal trees are not accustomed. The hazards of wind funnels are outlined on page 3.

To lessen the scar on the landscape, to decrease the possibility of wind funneling, and to retain the protective value of trees, consideration should be given to locating the lines where trees are less a factor, or to zigzagging lanes to lessen wind funneling and the landscape scar, particularly in areas of high scenic value. In the immediate vicinity of important buildings, in parks, and on some city streets, it may be practicable to place local distribution and communication lines underground. In other cases, local lines may be placed on poles of varied height, or alley arms may be used to minimize wire breakage, maintenance, and too frequent or too drastic trimming.

Special care should be taken when working on trees that are near power lines, especially if falling branches or trees may break the lines or endanger the worker. Work very close to high-tension wires should be done only by power-company employees or under their supervision.

Many wires are so situated that there is a natural tendency for branches of trees to continue to grow among them. In trimming such trees the branches should be encouraged to grow around and over the wires, so that their natural development can continue. If possible, directional pruning should be begun when the branches are small and while they are still a considerable distance from the wires.

In some wooded areas, low-voltage power and communication wires for local distribution are occasionally attached to tree trunks, either permanently or during construction operations. If poles are not used, such wires should be strung either on insulated brackets spiked to the trunks or on insulators supported by tie wires that are hung from lag screws or spikes inserted into the trees. From the standpoint of tree health and appearance, insulators supported by lag screws are preferable to brackets, as they can easily be clipped off when they have served their purpose. Wooden brackets, being more difficult to remove, are usually left on the trees.

Power and communication wires should never be wrapped around trees; tie wires should be so wrapped only in very temporary installations.

If wires must pass through tree branches, place them so as to keep pruning at a minimum and to prevent abrasion of the insulation. Broken insulation is a distinct safety hazard and may cause considerable loss of current, interruption of service, and sometimes injury to trees. Pruning for temporary wire clearance should be avoided whenever possible by stringing the wires where they have the least possible contact with trees.

PROTECTING ROADSIDE TREES

A shaded road is frequently so desirable as to justify extreme precautions to prevent injury to trees. In building roads through wooded or scenic areas, only the trees actually in the way of construction should be removed. Frequently, a survey will show that by sacrificing one tree the road can be located so as to prevent injury to several others. Winding roads that follow the natural curves and contours of the landscape are often preferred to straight ones. Wind funneling is less likely to develop on winding roads. If trees are scarce, it is usually desirable to locate roads so as to take advantage of the shade afforded by as many trees as possible.

The effect of necessary grade changes on roadside trees, and the work required to protect them, should be weighed with engineering considerations in determining road location. Important trees affected by cuts and fills should be treated as described under Raising Grades and Lowering Grades (pp. 4 and 13).

It is difficult to maintain the vigor of trees growing above or near the edge of road embankments. Tree roots may have been cut or the water table lowered. Soil may be washed from the roots until they are entirely exposed or until erosion of the embankment is stopped by the development of vegetation. Rapid runoff on a bare slope may prevent adequate penetration of water to the tree roots. The consolidation of the road foundation may cut off the moisture supply of trees.

It is difficult to cover cut slopes with vegetation, especially with trees. Raw, infertile, newly exposed road embankments are poor seedbeds for any kind of plant. The soil is usually exposed to more or less constant drying by sun and wind and in winter to alternate freezing and thawing. Some slopes will reseed naturally, many will not do so for many years, and others not at all. Adding topsoil and mulch and seeding will assist nature to restore vegetation on most road banks.

Mulching can be done with almost any kind of organic matter. On steep embankments it is often necessary to use stakes to prevent the mulch from slipping down the slope and being blown about by the wind. Both staked weed mulches and staked brush and litter mulches have been used with success. Old chicken wire is also satisfactory to hold mulches in place. Sometimes it is advisable to apply fertilizers on embankments and around the trees near the edge of embankments. Slopes and terraces around residences and along parkways may be covered by sod.

The surfacing of roads with concrete, asphalt, or other impervious material can be expected to kill at least part of the small feeding roots that are covered. Even if the road is not surfaced, the movement of vehicles

may so consolidate the soil as to weaken the feeding roots severely or to kill them. Prune such injured trees promptly and, if their value justifies it, stimulate their unaffected roots by the application of fertilizer.

Trees weakened as a result of the changes brought about by road construction, like those injured by other construction work, should receive prompt treatment. Delaying the treatment greatly increases the hazard.

SAFEGUARDING TREES IN PARKING AREAS

Large car parks are often unsightly. Shaded parking areas are cooler and improve the industrial landscape. In congested areas, however, the dispersal of parked cars among trees presents serious problems. Heavy construction equipment and freight vehicles require a solid parking pavement, which is difficult to construct among trees. Trees left along the edge of congested parking lots or scattered through them need special protection if they are to be kept healthy. Large rocks or similar guards help to prevent wounding of the trunks, but they should not be so placed as to create a hazard to automobiles or to injure part of the root area. It is difficult to predict how much root area can be covered by roads and parking areas without causing the death of the trees; factors such as the character of the soil, species of tree, vigor, and root distribution are important considerations. Especially with conifers, it is safer to leave undisturbed half or more of the root area.

The water-supplying capacity of the soil and the availability of adequate oxygen are important to normal tree growth. Soil packing, therefore, may seriously reduce the vitality of trees. Moving or parking automobiles results in packing the soil. The dripping of oil and grease from cars and trucks is another source of injury, not only because the oil may be toxic but also because it increases soil packing and forms a surface coating that keeps rain water from soaking in. Water readily runs off packed soil instead of being absorbed, and the movement of air and gases in the soil may be greatly retarded.

A gravel surface on the soil where cars are to be parked causes less consolidation of the soil particles and permits better air and water penetration than do more impervious materials.

Frequently peat moss worked into the upper 2 or 3 inches of soil before it is covered with gravel will conserve moisture and reduce soil compaction. To avoid cutting the small roots, a fork rather than a hoe or spade should be used in loosening the surface soil before applying peat moss and gravel.

If a choice is possible, locate parking areas on well-drained, light-textured soils. Such soils do not compact readily, nor is the subsequent aeration problem nearly so acute, especially if the soil is to be leveled off or surfaced. The tree roots that have not been covered by a parking surface should be fertilized and the humus content of the surrounding soil kept at a high level. Trees that are planted after the parking area has been established may have a better chance of survival, as their roots tend to develop where conditions are most favorable for growth.

Where there is considerable wooded area per car and where topography permits, it is often practicable to develop a one-way road system with numerous spurs to provide parking for one or two cars without seriously damaging the trees. If space permits, no tree need have more than a third of its root area covered. Locate paths or sidewalks for pedestrians and enforce their use, preferably by means of guardrails or other barriers,

so that there will be no unnecessary trampling of the soil beneath trees. Soil compaction by foot travel may be as damaging as that caused by automobiles.

If parking is permitted only in designated and prepared spaces, adjacent trees will have opportunity to extend their roots into the unaffected area and adapt themselves to the changed conditions. Fertilization, watering, mulching, and pruning may help those trees that are likely to be severely affected or that already show symptoms of decreased vigor. Human nature is such that instructions not to park outside the marked parking space are insufficient; obstructions or plantings are needed to protect the vital unpacked soil. Place large rocks or peeled logs to make parking and backing easy and to confine the cars to the proper spaces. If logs are used, the bark should be removed while they are still green to prevent insects breeding in these logs and possibly attacking weakened trees in the vicinity. Trees under which cars are parked should be systematically inspected and pruned to remove branches that would be likely to fall. Trees that are likely to blow over in severe storms should be removed.

TECHNICAL ASSISTANCE IN PLANNING CONSTRUCTION WORK

Time may be saved and mistakes avoided if competent assistance is obtained before plans are made for extensive or complex construction operations in forests or woodland or before treating trees that have suffered from widespread construction damage. Sometimes it may be desirable to consult local landscape architects, arborists, or other technical experts. Consultations may sometimes be arranged with city, State, or Federal authorities. The following Farmers' Bulletins of the United States Department of Agriculture may also be helpful:

1169F. Insects Injurious to Deciduous Shade Trees and Their Control
1586F. The Southern Pine Beetle
1826F. Care of Ornamental Trees and Shrubs
1896F. Care of Damaged Shade Trees

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